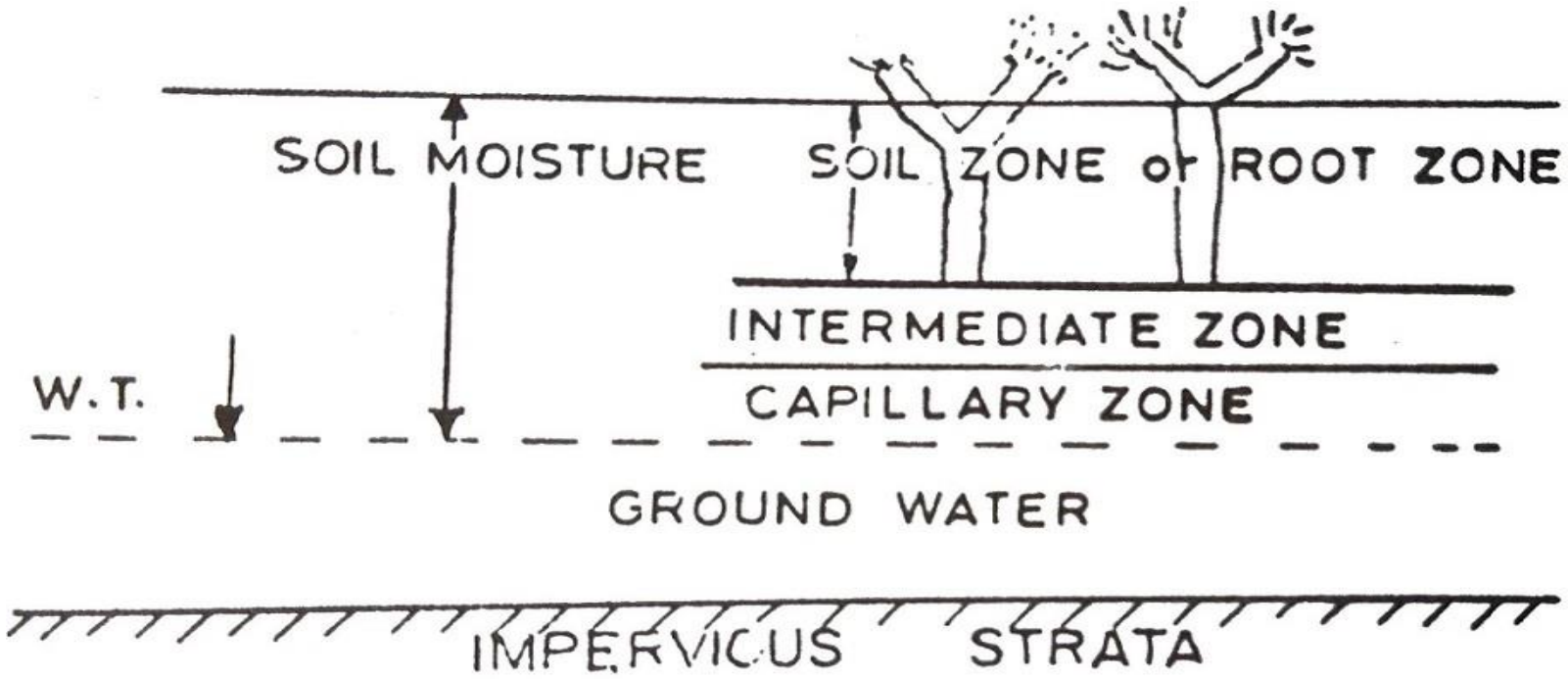
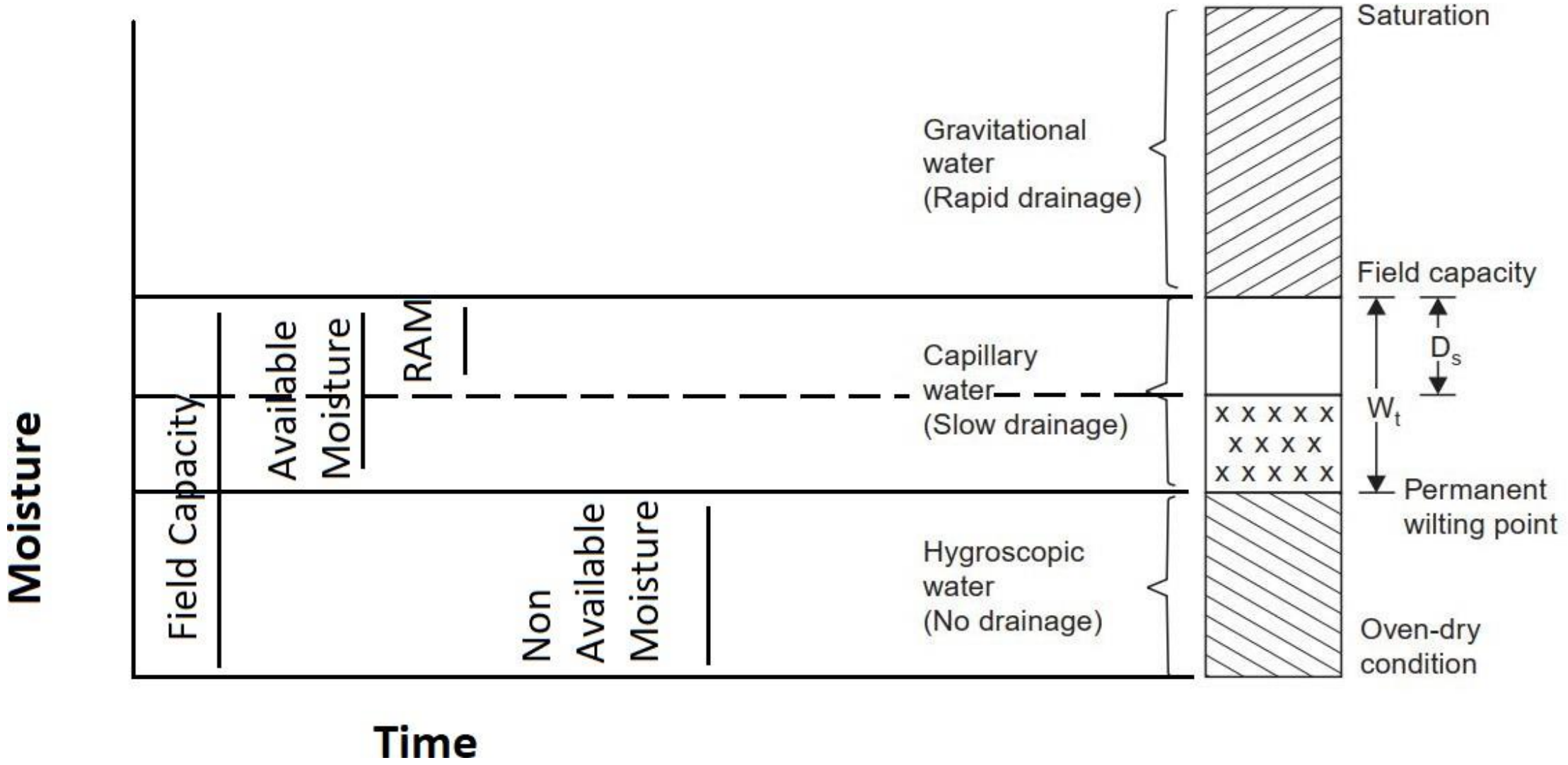
Soil Moisture Relation

- The water above water table is termed as soil-moisture while below as groundwater.
- ***Root zone depth:*** Maximum depth in soil strata upto which crops spreads its roots to extract water is called as root zone depth.
- excess and deficit affect crop growth and yield



Soil Moisture Relation



Soil Moisture Relation

Gravity water: The part of rainfall or irrigated water that flows down to water table under the action of gravity.

Capillary water: Water held by surface tension against gravity that can be extracted by plants by capillary action.

Hygroscopic water: The water that is attached to the soil molecules by loose chemical bond and hence is not available to plants

- Saturation Capacity: The water content of soil when all the pores are filled with water. It is the maximum water holding capacity of soil in root zone.
- Field Capacity: The water which cannot be drained under the action of gravity and is retained on surface of soil grain by molecular attraction or loose chemical bond(adsorption)

$$\text{FC} = \frac{Wt.of\ water\ retained\ in\ certain\ volume\ of\ soil}{Wt.of\ same\ volume\ of\ dry\ soil}$$

- Permanent wilting point(PWP): The water content at which plant can no longer extract sufficient water for its growth and wilts up
- Available moisture content(AMC): Difference of water content between field capacity and permanent wilting point
- Readily available moisture content(RAM): The portion of AMC that is most easily extracted by plants is called RAM. It is generally taken as 75% to 80% of AMC
- Optimum moisture content (OMC): Maximum water level upto which Moisture may be allowed to be depleted in root zone.
- Soil moisture deficiency: Water required to bring soil at a given water content to its field capacity.

If D be the root zone depth in meters and d be the equivalent depth of water in the soil of surface area A m2 Then,

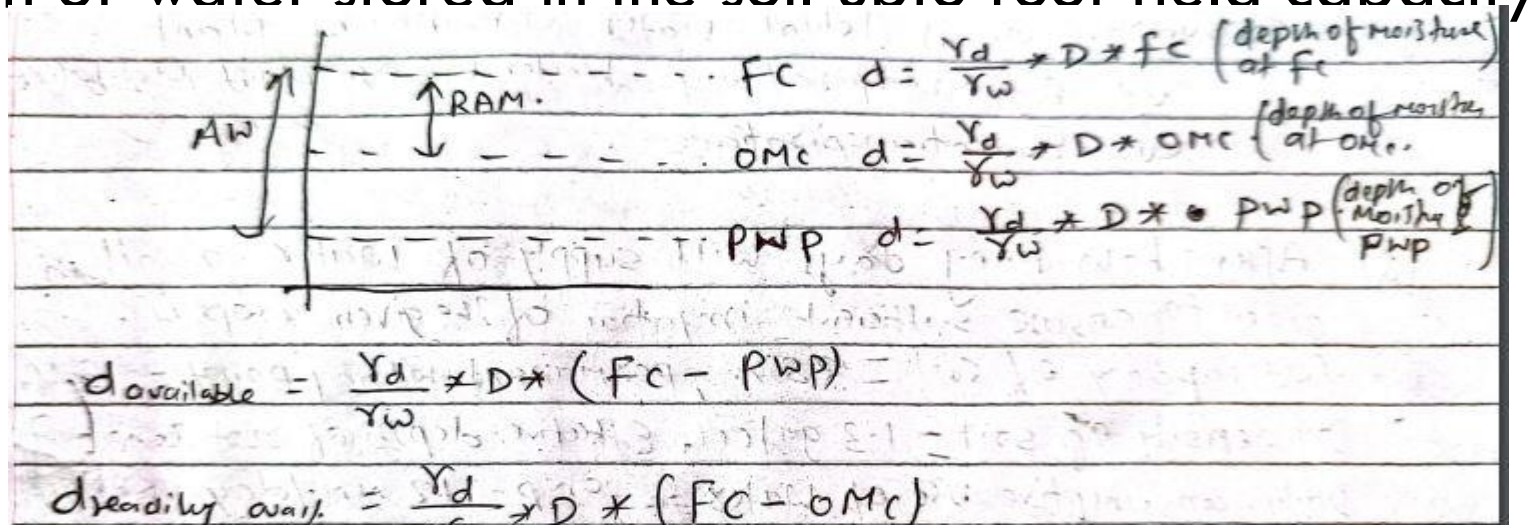
$$FC = \frac{Wt.of\ water\ retained\ in\ certain\ volume\ of\ soil}{Wt.of\ same\ volume\ of\ dry\ soil}$$

Let, γd = dry unit weight of soil (KN/m3)

$$FC = \frac{\gamma w * A * d}{\gamma d * A * D}$$

$$d = \frac{\gamma d * D * FC}{\gamma w}$$

This is depth of water stored in the soil upto root field capacity



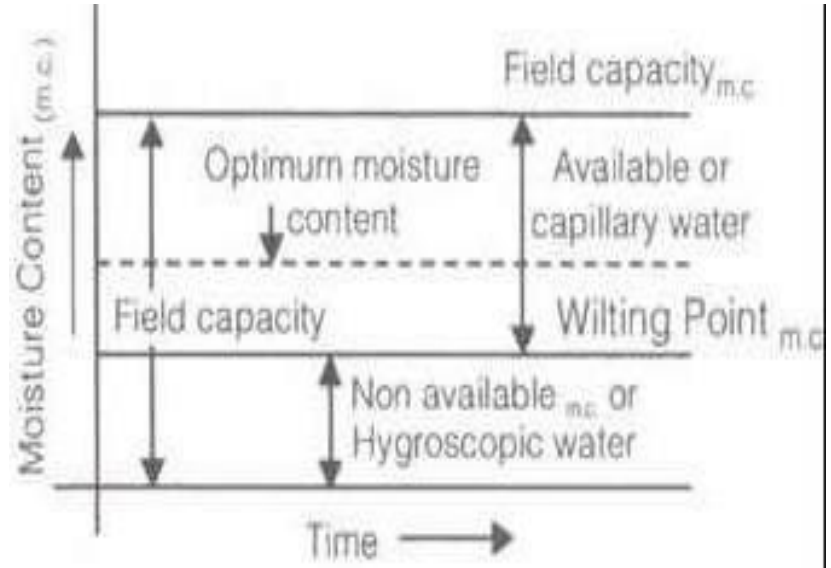
Depth and frequency of irrigation

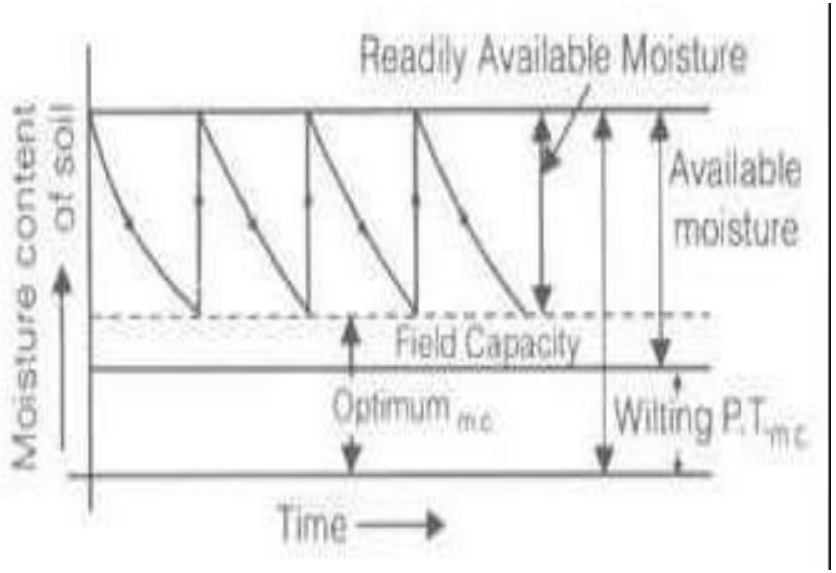
- Depth of irrigation required to increase moisture content from optimum moisture content to field capacity is given by

depth of water required (d)= $\frac{\gamma d * D * (FC - \mathrm{OMC})}{\gamma w}$ mm

Water required by plants = ETcrop mm/day

Thus, Irrigation interval = $\frac{Depth\ of\ water\ required}{\mathrm{ETcrop}}$





Irrigation efficiencies

- Water conveyance efficiency (ηc) – Ratio of the quantity of water delivered to the fields to the quantity of water diverted into canal system.

$$\eta c = \frac{Wf}{Wr} * 100$$

- Water application efficiency(ηa)- Ratio of the quantity of water stored in the root zone of the plants to the quantity of water delivered to the field.

$$\eta a = \frac{Ws}{Wf} * 100$$

- Water use efficiency(ηu)- Ratio of quantity of water used beneficially including the water required for leaching to the quantity of water delivered to the field.

$$\eta u = \frac{Wu}{Wf} * 100$$

Irrigation efficiencies

- Water storage efficiency (η_s) – Ratio of water stored in the root zone during irrigation to the quantity of water required to bring the moisture content of soil to the field capacity.

$$\eta_s = \frac{Ws}{Wn} * 100$$

Wn=Field capacity- available moisture in soil before to irrigation

- Water distribution efficiency(η_d)- Uniformity coefficient.

It evaluates the extent to which water is uniformly distributed.

$$\eta_d = (1 - \frac{\mathrm{d}}{\mathrm{D}}) * 100$$

d=average numerical deviation in depth of water stored

D=average depth of water stored in field

Crop Water Requirement

- Quantity of water required by the crop from the time it is shown to time it is harvested is called as crop water requirement.
- Factors affecting crop water requirement are climate, type of soil, effective rainfall etc
- Consumptive Use(Cu): Total amount of water used by the plants in transpiration (building plant tissue) and evaporation form plant adjoining area in any specified duration of time. Unit mm/day

  Cu = Evapotranspiration + water used in plant metabolism

  Cu= Evapotranspiration

  (Neglecting water used in plant metabolism)
- Effective rainfall (Re): Rainfall during crop growing period which is available to meet the consumptive use requirement of the plant

- **Consumptive Irrigation Requirement (CIR)**

It is the quantity of water actually required by plant. If natural rainfall provides a part of consumptive use, the consumptive irrigation requirement is given as:

$$CIR = Cu - Re$$

Cu= Consumptive Use, Re = Effective Rainfall

- **Net Irrigation Requirement (NIR)**

In addition to CIR, NIR takes into consideration of leaching requirement as well as pre sowing requirement.

$$NIR = CIR + LR + PSR + NWR$$

where,

LR = Leaching requirement PSR = Pre-sowing requirement

NWR = Nursery water requirement

- **Field Irrigation Requirement (FIR)**

In addition to NIR, FIR takes into consideration of water application loss i.e amount of water lost as surface runoff and through deep percolation.

FIR = NIR + Application Losses

$$FIR = \frac{NIR}{\eta a}$$

ηa = Water application efficiency

- **Field Irrigation Requirement (FIR)**

In addition to FIR, GIR takes into consideration of water conveyance loss through canal system by evaporation and seepage.

GIR = FIR + Conveyance Losses

$$GIR = \frac{FIR}{\eta c}$$

ηc = Water conveyance efficiency

Numericals

- Calculate the irrigation interval and depth of irrigation at the outlet of field with given data.

Field Capacity = 40%

Permanent Wilting Point = 16%

Effective depth of root zone = 70 *cm*

Dry Density of Soil = 1.5 *gm/cc*

Consumptive Use of Water , ET_c = 5*mm/day*

RAM = 80% *of available moisture*

Ans: Depth = 20.16 *cm and Irrigation interval* = 40 *days*

Numerical

(Q) Wheat is to be grown in a field having a field capacity equal to 27% and the permanent wilting point is 13%. Find the storage capacity in 80cm depth of soil, if dry unit weight of soil is 14.72 KN/m^3. If the irrigation water is to be supplied when the average soil moisture falls to 18%, find the depth required to be supplied to the field if field application efficiency is 80%. What is the amount of water needed at he canal outlet if the water lost in water courses and field channels is 15% of outlet discharge?

- Ans 15.88 cm

Numerical

Q.N With the following data:

FC = 80% PWP = 35%

Root depth = 60 cm Soil density = 1.5 gm/cc

ETc = 5 mm/day Application efficiency = 80%

Conveyance loss = 55% Distribution efficiency = 65%

Calculate;

Available moisture content

Readily available moisture contents

Irrigation interval

Depth of irrigation at outlet of the field

The requirement of head work

- Solution;
- Available moisture content (AMC) = FC – permanent wilting point (PW P)
  = (80-35)% = 45%
- Readily available moisture content (RAM) = 80% of AMC = 0.8*45% = 36%
- Depth of water available for consumptive use = $\frac{d*\gamma d*F}{\gamma w} = \frac{d*\gamma d*RÆM}{\gamma w} = \frac{1.5*0.6*0.36}{1} = 32.4$ cm
- Irrigation Interval = $\frac{0.324}{\frac{5}{1000}} = 64.8$ days
- Field irrigation requirement = $\frac{\text{Consumptive use}}{\text{Water application efficiency}} = \frac{0.324}{0.8} = 0.405$ m
- Depth of water at outlet of field = 0.405 m
- Irrigation requirement at head work = $\frac{0.405}{0.55*0.65} = 1.133$m

Additional Questions

1) Wheat is to be grown in a field having field capacity of 27%. and PWP of 13%. Find the storage capacity in 80 cm depth of soil, if dry unit wt. of soil is 14.72 KN/m³. If irrigation water is to be supplied when soil moisture falls to 18%. find the water depth required to be supplied to the field if the field application efficiency is 80%. What is the amount of water needed at the canal outlet if the water lost in the water-courses and the field channels is 15% of the outlet discharge?

Soln:

F.C = 27%.
PWP = 13%.
root zone depth (d) = 80cm
density of soil (γ_d) = 14.72 KN/m³ = 1500 Kg/m³

η_a = 80%.
Conveyance loss = 15%.
$\therefore \eta_c$ = 85%.

Storage capacity or Available moisture = $\frac{\gamma_d \times d \times (FC - PWP)}{\gamma_w}$

$= \frac{1500 \times 0.8 \times (27-13)}{1000 \times 100}$

$= 0.168m = 16.8cm$

Since moisture is allowed to fall till 18% only

RAM = 27% - 18% = 9%

available depth of irrigation water = $\frac{1500 \times 0.8 \times 9}{1000 \times 100}$

$= 0.108m = 10.8cm$ (N.I.R)

Considering field application efficiency of 80%. i.e 20% of water is lost in field application,

field irrigation requirement (F.I.R) = $\frac{NIR}{\eta_a} = \frac{10.8}{0.8} = 13.5cm$

Amount of water at canal outlet = $\frac{FIR}{\eta_c} = \frac{13.5}{0.85} = 15.88cm$

2) 800m³ of water is applied to a farmer's rice field of 0.6ha, when the moisture content in the soil falls to 40% of available moisture. Determine the field application efficiency, if FC = 36%. PWP = 15%, root depth = 60cm and porosity = 0.4

Soln:

PWP = 15%.
FC = 36%.
root depth (d) = 60cm
porosity (n) = 0.4
volume of water applied in field = 800m³
Area (A) = 0.6ha

We know,

$f = \frac{\text{wt. of water}}{\text{wt. of soil}}$

or, $f = \frac{\gamma_w \times V_v}{\gamma_d \times V}$, V_v = volume of voids

or, $f = \frac{\gamma_w}{\gamma_d} \times n$ $\left[\because n = \frac{V_v}{V}\right]$

or, $0.36 = \frac{1}{\gamma_d} \times 0.4$ $\therefore \gamma_d = 1.111 gm/cc$

Since, irrigation is done when moisture content falls to 40% of available moisture.

RAM = 60% of (FC - PWP) = 0.6 × (36 - 15) = 12.6%.

available depth of irrigation water = $\frac{\gamma_d \times d \times RAM}{\gamma_w}$

$= \frac{1.111 \times 60 \times 12.6}{1 \times 100}$

$= 8.4cm$ (W_s)

W_s → depth of water stored in root zone

W_f → depth of water applied in field

$W_f = \frac{\text{volume of water applied}}{\text{Area}} = \frac{800}{0.6 \times 10^4} = 0.133m = 13.3cm$

Now,

$\eta_a = \frac{W_s}{W_f} \times 100\% = \frac{8.4}{13.3} = 63.15\%$.

3) A sandy loam soil holds water at 140 mm/m depth between FC and PWP. Root depth is 30cm and the allowable depletion of water is 35%. The daily water use by the crop is 5mm/day. The area to be irrigated is 60ha and water can be delivered at 28 lps. Application efficiency is 40%. Determine volume of water required and also time to irrigate 4ha land at supply of 28 lps

Soln:

Available moisture = 140 mm/m
root zone depth = 30cm = 0.3m
$\eta_a = 40\%$ Area = 60ha
$ET_o = 5$ mm/day

∴ Total available moisture = $140 \times 0.3 = 42$ mm

RAM = 35% of available moisture
$= 0.35 \times 42 = 14.7$ mm (N.I.R)

Frequency of irrigation (irrigation interval) = $\frac{\text{readily available moisture}}{ET_o}$

$= \frac{14.7}{5}$

$= 2.94 \approx 2$ days

$FIR = \frac{NIR}{\eta_a} = \frac{14.7}{0.4} = 36.75$ mm

volume of water to be applied in field = $\frac{36.75}{1000} \times$ Area

$= \frac{36.75}{1000} \times 60 \times 10^4$

$= 22050\ m^3$

volume of water to irrigate 4ha = $\frac{36.75}{1000} \times 4 \times 10^4$

$= 1470\ m^3$

Rate of supply = 28 lps = $28 \times 10^{-3}\ m^3/s$

∴ Time required = $\frac{\text{Volume}}{\text{rate}} = \frac{1470}{28 \times 10^{-3}} = 52500$ sec $= 14.58$ hr.

4) Daily consumptive use of crop is 5mm. Canal may operate from 6AM to 5PM only. Available moisture for given soil is ~~220~~ 220 mm per m and root zone depth is 1.2m. Assume only 50% of soil moisture is available for crop. Application efficiency is 65%. Calculate discharge required if CCA is 450 ha. Calculate irrigation interval and outlet discharge.

Soln,

CCA = 450 ha = $450 \times 10^4\ m^2$ $\eta_a = 65\%$

$ET_o = 5$ mm/day

Available moisture = 220 mm/m

root depth (d) = 1.2m

∴ Total available moisture = 220×1.2
$= 264$ mm

RAM = 50% of AM = $0.5 \times 264 = 132$ mm (NIR)

Irrigation interval = $\frac{132}{5} = 26.4$ days

$FIR = \frac{NIR}{\eta_a} = \frac{132}{0.65} = 203.07$ mm

volume of water required = $\frac{203.07}{1000} \times 450 \times 10^4$

$= 913846.153\ m^3$

volume required in a day = $\frac{913846.153}{26.4}$

$= 34615.38\ m^3$

Total hours of canal operation required = 13hrs $= 13 \times 60 \times 60$
$= 46800$ sec

Discharge in canal = $\frac{\text{volume}}{\text{time}}$

$= \frac{34615.38}{46800} = 0.74\ m^3/sec$